



Proceedings of the Eurosensors XXIII conference

Snapshot Mask-less fabrication of embedded monolithic SU-8 microstructures with arbitrary topologies

P. Preechaburana¹, D. Filippini^{1*}¹*Division of Applied Physics, Department of Physics Chemistry and Biology, IFM – Linköping University, Linköping, Sweden.*

Abstract

Microscope projection lithography offers an affordable alternative for fast prototyping of 3D polymer microstructures. Here we introduce a 3D mask-less approach operating on a routine epi-fluorescence microscope that enables the fabrication of 3D microstructures such as lenses, pillar forests, cavities and channels embedded in a monolithic SU-8 structure defined in a single exposure step. Fabrication times of about 1 hour from design to finished structure are achieved and 5 μm resolution is possible in the present configuration.

SU-8 microstructures; mask-less photolithography; microlenses; microscope projection lithography; composed lenses; capped cavities.

1. Introduction

The micro-fabrication of complex 3D structures is relevant to microelectromechanical systems (MEMS), micro-fluidic devices, miniaturized sensors, and optical devices [1,2]. Diverse fabrication methods are available, from production-level processing requiring high-quality, expensive equipment and facilities, to quick and inexpensive methods for fast prototyping. Among the second type micro-stereo lithography (μSL), and specially microscope projection lithography systems (MPLS) using patterned illumination controlled by digital micro mirror devices (DMD), offer affordable, versatile and direct conversion of computer designs into 3D polymer microstructures [3,4], while avoiding the development of precision photomasks and associated processes.

In contrast with the sequential exposure in μSL systems, mask-less fabrication on regular microscopes offer 3D structuring in a single exposure by using gray-level and/or color patterned illumination. Still, all these methods require at some point to assembly the structures in order to confine samples within a controlled environment where reactions and measurements can take place. This typically implies extra manufacturing steps involving alignment and sealing procedures, which can turn useless an almost finished structure.

* Corresponding author. Tel.: +46 013 281282.

E-mail address: pakpr@ifm.liu.se, danfi@ifm.liu.se.

Here we introduce a 3D mask-less approach operating on a routine epi-fluorescence microscope that enables the fabrication of 3D microstructures such as lenses, pillar forests, cavities and channels embedded in a monolithic SU-8 structure defined in a single exposure step.

2. Experimental

Fig.1 shows the diagram of our fabrication platform. SU8-10 spin-coated glass slides (30 μm thick film) are exposed on the microscope stage of a Zeiss Axiovert 40 inverted routine microscope through a 10X (0.25) A-Plan objective in the epi-fluorescence configuration. In our setup we replaced the light source by a commercial digital light processing (DLP) projector (Optoma EP1690) operating at a 1280x800 pixels spatial resolution. The working illuminating area in these conditions is $\sim 4\text{ mm}^2$, and different ranges and resolutions can easily be achieved by switching objectives. A 50 mm Nikon lens is used to convey the patterned illumination towards the objective and a mirror is introduced in the filter holder to deflect the beam. The inset in the figure show the spectral radiance of pure white illumination measured with a Ocean Optics USB 2000 fiber optics spectrometer.

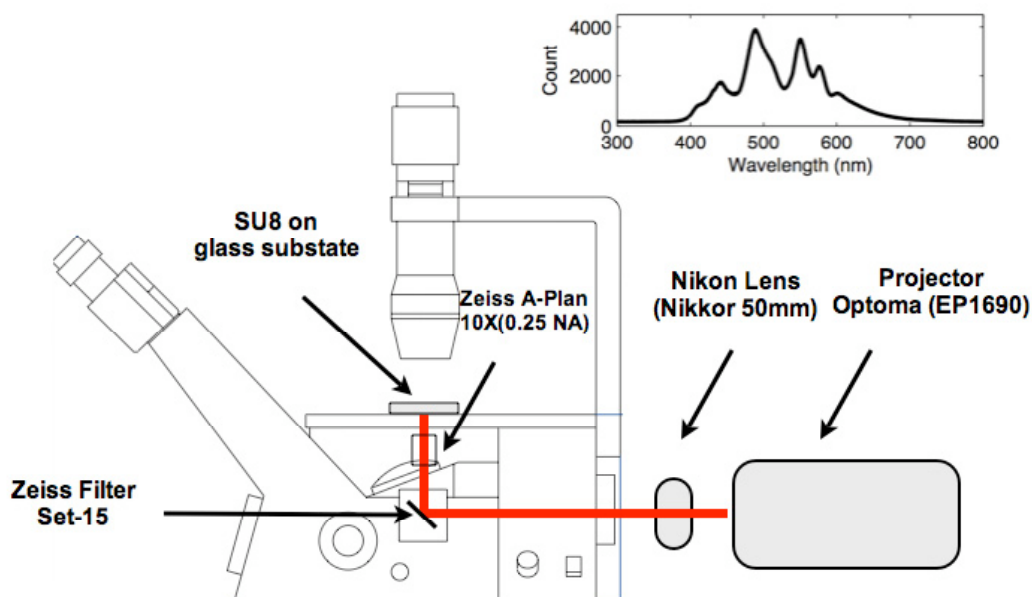


Fig. 1: Scheme of the mask-less exposure setup. The illumination channel for epi-fluorescence in a routine Zeiss Axiovert 40 microscope is used to expose SU-8 coating a glass slide (illumination through the glass slide is also possible). A mirror is added to the standard filter cube to direct the light through a 10x (0.24 NA) objective. The illumination is provided by a DLP projector (Optoma EP1690) aided by a Nikon lens.

3. Results and discussion

Fig. 2a shows a illuminating pattern used for exposure. This is implemented as a bitmap image displayed with the Matlab 'imshow' function in order to control the illumination of each single pixel and avoid the ubiquitous anti-aliasing in alternative graphic utilities. This image is taken by the DLP device and projected to the SU-8 through the standard optics of the epi-fluorescence illumination of the microscope.

For a given configuration (Nikon lens, microscope objective, etc.) the smallest feature size is defined by the smallest element that can be displayed on the screen (or projector), which is one individual pixel. On the other hand the distance between two minimal features in the final microstructure is limited by the contrast of the projector, the

particular gamma settings and the geometry of the intended microstructure. Fig. 2b demonstrates that for a 10x objective and $\gamma = 1$ the minimum achievable feature is about $5\text{ }\mu\text{m}$, with about $15\text{ }\mu\text{m}$ of minimum separation between them (see hollow pillars in the figure). For the SU-8 10 used in this work, we have achieved 5:1 aspect ratios as illustrated by the pillars in the inset of Fig. 2b.

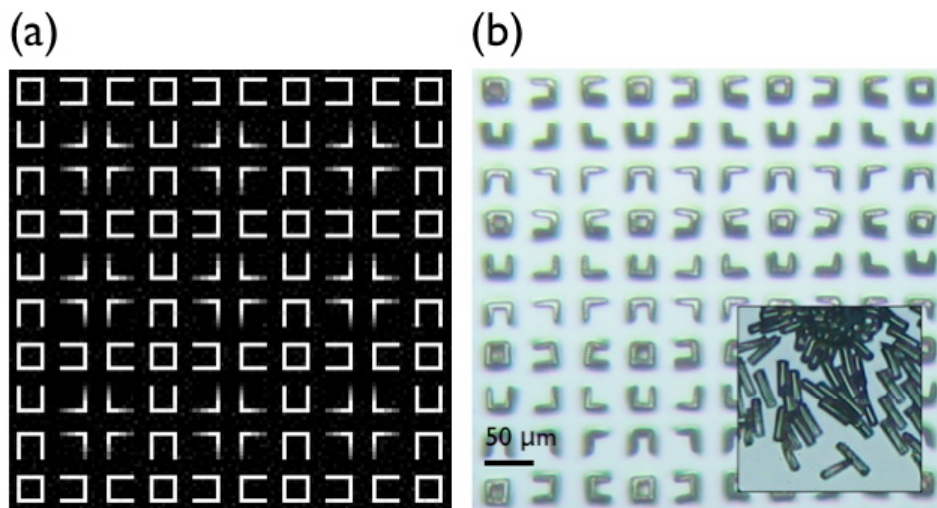


Fig. 2a) Exposure pattern. b) Resulting SU-8 microstructures with minimum wall widths of $5\text{ }\mu\text{m}$. The inset illustrates 5:1 aspect ratios achievable for individual pillars.

Fig. 3 collects examples of 3D microstructures. In contrast with conventional photolithography, the mask-less systems naturally enable gray level and color illuminating patterns with the same simplicity as with binary masks. Fig. 3a exemplifies control of surface topology of 5 different lenses achieved in a single exposure process. Any arbitrary geometry, convex or concave can be realized just by designing the illuminating profile. Considering a 8 bits (255 intensity levels) resolution for the illuminating gradient, and considering a typical stability of 1 intensity level we can estimate a resolution in the thickness direction of $\sim 360\text{ nm}$. Exact matching of exposure profiles and the resulting microstructures just demand a calibration of the projector's gamma value.

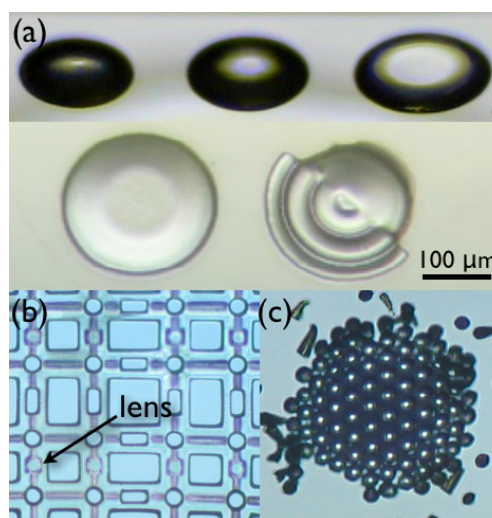


Fig. 3: a) SU-8 micro lenses with arbitrary curvature or topology. b) Micro channels with embedded lenses produced in a single fabrication step. c) Compound lens with topology control of each single element.

Fig. 3b shows a combination of channels, lenses and reservoirs integrated in a single SU-8 structure.

Fig. 3c illustrates the use of gray level exposure and planar resolution by composing a lens from conic pillars with different heights. To achieve smaller spacing between pillars we use a Cr mask transferred [5] to the glass substrate prior to the SU-8 deposition and we exposed the lens pattern through the metal mask. The mask transfer procedure itself is a method for channel and cavity formation in a single SU-8 exposure that adds the possibility to introduce a self-aligned metal electrode within monolithic cavities and channels.

Fabrication times from pattern generation to finished SU-8 microstructures is up to 1 hour depending on whether a mask transfer procedure is used or not. It must be noticed that the metal mask used in such case is also created with the mask less platform.

4. Conclusions

The present work has demonstrated a versatile approach for fast prototyping of 3D SU-8 microstructures. Arbitrary 3D topologies, compound elements and enclosed spaces with or without self aligned electrodes were created using a routine epi-fluorescence microscope in combination with a DMD based projector, which replace multiple assembly steps and mask fabrication in conventional approaches.

References

1. Madou M J. *Fundamentals of microfabrication*. Boca Raton, Florida: CRC; 2002.
2. Whitesides G M. The origins and the future of microfluidics. *Nature* 2006;**442**:368-373.
3. Sun C, Fang N, Wu D M, Zhang X. Projection micro-stereolithography using digital micro-mirror dynamic mask. *Sensors and Actuators A* 2005;**121**:113-120.
4. Taff J, Kashte Y, Spinella-Mamo V, Paranjape M. Fabricating multilevel SU-8 structures in a single photolithographic step using colored masking patterns. *J. Vac. Sci. Technol. A* 2006;**24**:742-746.
5. Macken S, Filippini D. Monolithic SU-8 microcavities for efficient fluorescence collection, *J. Micromech, Microeng.* 2009: in press.